**Memorandum**

U.S. Department of Transportation
**Federal Aviation Administration**

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| Subject: | **INFORMATION:** Use of Structural Dynamic Analysis Methods for Blade Containment and Rotor Unbalance Tests | Date: | March 8, 2001 |
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## 1. Purpose

This policy provides guidance for evaluating the use of structural dynamic analysis methods to show compliance with the requirements of §33.94 of Title 14 of the Code of Federal Regulations (14 CFR 33.94), "Blade containment and rotor unbalance tests." This policy specifically addresses paragraph (a) of §33.94

for engine design and configuration changes. This policy is derived from extensive Federal Aviation Administration (FAA) and industry experience in evaluating compliance with the pertinent regulations. This policy does not create any new requirements.

**2. Background**

Engine manufacturers are developing and using various types of structural dynamic analysis methods to support both engine certification activities and the aircraft manufacturers' certification activities. These structural dynamic analysis methods include various types of mathematical models, such as two dimensional and three dimensional finite element models of the engine and installation. These models are used to determine loads and perform structural dynamic analyses on the engine rotating components, static structures, mounts, and other components as needed to simulate the engine test stand or aircraft installation. One such aircraft level assessment examines windmilling imbalance using the methods described in the Aviation Rulemaking Advisory Committee (ARAC) report, "Engine Windmilling Imbalance Loads - Final Report," dated July 1, 1997, and the associated advisory circular (AC) 25.24 "Sustained Engine Imbalance," dated August 2, 2000. Although the ARAC report and AC state that these dynamic analysis models should be validated by data obtained during a §33.94 engine test, the validation associated with these airplane requirements does not substantiate the use of these dynamic analyses as a substitute for conducting the blade out tests required by §33.94.

Section 33.94 requires an engine test to demonstrate failure of the most critical fan, compressor, or turbine blade. Typically, the engine test is run on the first engine of an engine type to establish an acceptable baseline configuration. When there is a major change to the engine, the effect of the change on the §33.94 requirements is evaluated to determine if the results from the baseline test are applicable. This is referred to as reconciling the change with the baseline configuration. Dynamic analysis is just one method used in the reconciliation process. When engine changes cannot be appropriately reconciled with the baseline configuration, a new baseline test may be necessary. An analysis cannot substitute for a baseline engine test. However, the results of a baseline engine test can be used to develop, validate, and calibrate an engine dynamic analysis. Thus, the engine dynamic analysis, when shown to be acceptable, may be used to support future §33.94 compliance findings for some engine design and configuration changes.

**3. General**

When changes are made to an existing engine type certificate or derivatives are added to the type certificate, these changes must be reconciled with the baseline engine test. The analysis that reconciles the new configuration with the baseline engine test may vary from a qualitative engineering evaluation to the use of a complex dynamic model, depending on the extent of the modifications. In all cases the analysis must be validated with respect to the baseline engine test before it can be used for extrapolation to the new configuration. The analysis is usually validated by showing that it can reliably predict applicable results from engine tests or rig tests. The analysis should consider the period from just before blade loss through the deceleration rundown for 15 seconds or until a self-induced shutdown.

To reconcile an engine change with the baseline configuration, the objectives of §33.94 must be met. Therefore, the reconciliation must show that, following failure of the most critical fan, compressor, or turbine blade and when operated for 15 seconds or until a self-induced shutdown, the engine:

- Will not fail its mounting attachments;
- Will not catch fire; and
- Is capable of containing the damage.

**4. Loads Evaluation**

The reconciliation of an engine change with the baseline configuration using analysis methods should involve an evaluation of loads. The baseline engine test loads should include the effects of the test configuration used to support the engine during the baseline blade out test; the changed engine loads should be evaluated against the baseline engine test results. This evaluation should verify that the changed engine loads are consistent with any applicable limitations (for example, engine or thrust reverser mount structure loads) noted within the installation instructions required under §33.5 and the engine mount load limits established under §33.23.

**5. Mount Evaluation**

The mount evaluation generally focuses on loads and the vibratory response of the engine. The analysis should show that proposed changes to the engine do not significantly modify mount loads from the baseline engine test results. If the resultant mount loads are higher, further evaluation should be conducted to show that the mounts have sufficient capacity. Mount loads and load distributions that are significantly higher than the baseline engine test results generally indicate that the new configuration cannot be reconciled to the baseline engine test. In this case a new blade out engine test may be required to show compliance with §33.94.

**6. Fire Evaluation**

The fire evaluation generally focuses on the loads and vibratory response of components that carry flammable fluids, such as: fuel lines, oil lines, oil tanks, gearboxes, or integrated drive generators. The analysis should show that the change to the engine does not increase the loads and response of these components. If the loads and response are increased, further evaluation should be conducted to show that the components will not fail or catch fire. An evaluation should also be conducted when changes are made to those components that carry flammable fluids, to assess that the changes are acceptable.

**7. Blade Loss and Containment Evaluation**

Containment capability is dependent on the containment structure and blade loss interaction, including blade fragmentation and the resulting interaction between the blades and the case. The applicant should show by test, validated analysis, or both that changes to the blade or containment structure can be reconciled with the baseline engine test. Containment rig testing, combined with dynamic analysis, is one method that may provide the appropriate data to reconcile with the baseline engine test. When the unbalance loads due to blade loss are significantly higher than demonstrated during the baseline engine test, reconciliation of the change with the baseline test may not be possible. In those cases a new engine test is required by §33.94.

Changes to the fundamental method of containment, such as changing from hardwall containment to softwall containment or introducing design changes to the same case, may affect the containment capability of the engine as well as the load transfer from blade fragmentation and the resulting interaction between the blades and the case. Therefore, it should be shown that, in addition to containment capability, the changes do not significantly affect the overall engine loads. This can be shown by test or by dynamic analysis that has been validated by showing that it can reliably predict event outcomes for changed products.

**8. Static Structure**

The analysis method should include the loads and the load transfer through the engine structure for 15 seconds or until a self-induced shutdown. Changes to the static structure may significantly alter the loads.  For example, increasing the engine case stiffness and strut stiffness may result in higher loads to the engine mounts.  The dynamic analysis should be sufficiently detailed to address these changes.

**9.  Applicable Changes**

The use of analysis to reconcile major engine changes with a baseline §33.94 engine test is a decision that requires substantial engineering judgement.  Major engine changes include, but are not limited to, changes to the following:

- Blade count, blade mass, blade platform or blade design;
- Materials in the blade, containment, or attachment structure;
- Maximum rotational speed;
- Containment structure;
- Static structure;
- Mount locations;
- Mount structure; and
- Location or design of a component that carries flammable fluid.

**10.  Concluding Remarks**

When analysis is proposed to reconcile major engine changes, the applicant and the Engine Certification Office (ECO) or cognizant Aircraft Certification Office (ACO) should agree on the method of compliance early in the certification program.  They should include the Engine Dynamics National Resource Specialist and the Engine and Propeller Standards Staff in the decision process when necessary.

Original signed by J. J. Pardee

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DRAFT:  This document does not represent final agency action on this matter and should not be viewed as a guarantee that any final action will follow in this or any other form.